

R3
960 Vol. V. No. 4.
R57

STORAGE

FEBRUARY, 1912

v.5
no. 4
cop. 1
Biological
& Medical
Serials

TRANSACTIONS

OF THE

ROYAL
SOCIETY OF TROPICAL
MEDICINE AND HYGIENE.



London :

SOCIETY OF TROPICAL MEDICINE AND HYGIENE,
11, CHANDOS STREET, CAVENDISH SQUARE, W.



TRANSACTIONS
OF THE
SOCIETY OF TROPICAL MEDICINE
AND HYGIENE.

FEBRUARY, 1912.

VOLUME V. No. 4.

Proceedings of a Meeting of the Society on Friday, January 19th, 1912,

Sir WILLIAM LEISHMAN, F.R.S., *President*, in the Chair.

FILARIASIS IN FIJI.

BY

P. H. BAHR, M.A., M.B., B.C., D.T.M. & H. (Camb.).

The researches, of which I propose to give a summary, were carried out in the Fiji Islands during the year 1910. There are certain local conditions to which it is necessary to refer at the outset, inasmuch as they had a distinct bearing on my work.

Fiji consists of a group of islands, estimated at over 250 in number, of which only the larger are to any extent inhabited. These islands are spread over an area—land and water—approximately five times that of Wales. The more important islands are of volcanic origin, but are clothed to their summit with dense vegetation, and surrounded by coral reefs of varying size and extent. The aboriginal natives, or Fijians, belong to the darker of the Polynesian races and number 87,000; but besides these there have been immigrations of other races, immigrations which, from the point of view of our present study, are specially important.

There is the large East Indian population of 39,000, imported as coolies for work on the various cocoanut, sugar and banana plantations; a smaller number, 3,000, of Solomon Islanders, 3,000 Europeans, and 1,800 European-Fijian half-castes.

At the close of their term of indenture, the Indian coolies are encouraged to take up land and settle in Fiji, whereas the Solomon Islanders mostly return to their own homes.

The Indians and Fijians do not intermingle to any extent; inter-marriage is almost unknown.

The Fijians themselves are not agriculturists and are unsuited for work on the plantations. The land is held by them on a communal system.

The climate is cool for the Tropics and remarkably uniform throughout the year. The hottest season extends from November to March; the highest temperature recorded in 1910 was 96° F. in February, and the lowest 61° F. in July. The rainfall is a large one; it measured 107 inches in 1910. The seasons of greatest heat and of largest rainfall correspond as a general rule.

The anopheles mosquito is absent, and consequently malaria is not found as an indigenous disease.

Yaws is common among the Fijians, but syphilis is quite unknown amongst them, though prevalent amongst the East Indians.

Bacillary dysentery occurs yearly in epidemic form, but is mostly confined to the gaols and to the plantation coolies. Leprosy and tuberculosis are also found, the latter carries off the natives with alarming rapidity, wherever they come into intimate contact with white men.

An epidemic of measles occurred in 1874 and swept off over a quarter of the population.

Very early in the modern history of the Pacific, the extreme prevalence of elephantiasis in the various groups of islands was noted, and when the relationship of the *Filaria sanguinis hominis* to this disease began to be recognised, certain investigators remarked on the extreme prevalence of the filaria in the blood of the natives—Samoa for example—where it was estimated that from 1·3 to 1·20 of the total population had elephantiasis.

From blood slides from cases of elephantoid disease sent from Samoa to MANSON, it was found that over half of such patients harboured

microfilariae. In Fiji, LYNCH, BRUNWIN and WILSON found filarial embryos in the blood of 24 to 38 per cent. of all natives examined.

The value of many of these observations, in Pacific islanders as well as in the natives of other countries, as regards filarial embryos in the bloodstream would have been much enhanced if the various workers had followed the same methods and had specified the time their examinations were made and the amount of blood scrutinized. Throughout the course of my investigation the technique described by MANSON in his "Tropical Diseases" and the method of measuring definite quantities of blood as described by Low, was the one employed. In enumerations of microfilariae each of my observations recorded applies to 16 cmm. of blood.

My investigations on filariasis in Fiji were directed more especially to the Fijians, and confirmed many of the observations of previous workers. I have arrived at certain conclusions, and these I will in the first instance state categorically, and then proceed to discuss the conclusions and the data on which they are founded.

I. A large proportion of all Fijians (27.1 per cent.) harbour microfilariae in their blood: this figure, however, probably does not represent the aggregate liability of these people to filarial infection. Adult filariae were found in the lymphatics, especially the lymphatic glands, without the presence of the corresponding microfilariae in the blood. Again a large proportion of Fijians are affected with lesions commonly regarded as being of filarial origin, in whom no microfilariae could be found in the blood; that is to say, I found that the proportion of Fijians carrying microfilariae (27.1 per cent.) added to the total affected by filarial disease but without microfilariae (25.4 per cent.) represented no less than 52.5 per cent. of the entire population. Moreover, I found that all Fijians, as well as foreigners for some time resident in Fiji, exhibited a well-marked eosinophilia, and this even in the absence of evidence of infection with intestinal or other metazoal parasites. In addition to this, I may add that microfilariae have been observed to disappear from the bloodstream of patients while under observation. So it is not unreasonable to conclude that nearly every Fijian has, at one time or another, been the subject of filarial invasion.

II.—(1). At the present state of knowledge it cannot be stated definitely whether the Fijian filaria is a new species or a local variety, or whether it is really *Filaria bancrofti* with the habit of its microfilariae

as regards periodicity modified by local circumstances. There are certain reasons in favour of its being a new species and others, apparently equally good, against that supposition. In favour of its being a new species are the following:—

(a) The larval form (microfilaria) exhibits in the blood no periodicity, contrary to what happens in the case of *Filaria bancrofti*; it occurs in equal abundance in the blood at all hours of the day or night.

(b) While capable of development in *Culex fatigans*—the favourite intermediary host of *Filaria bancrofti*—this mosquito is not nearly so efficient an intermediary in Fiji as it is in other countries, or as is *Stegomyia pseudoscutellaris* (Theobald), the common mosquito of this group of islands.

(2). In favour of the Fijian filaria being identical with *Filaria bancrofti* we have the following facts:—

(a) The Fijian microfilaria is morphologically identical with *Microfilaria bancrofti*.

(b) The parental form of this microfilaria is, as far as can be ascertained, identical with *Filaria bancrofti*.

(c) Both nematodes live in the same tissues and are associated with the same diseases.

(d) The same mosquito, *Stegomyia pseudoscutellaris*, is an efficient intermediary for *Filaria bancrofti*.

III. Assuming that the Fijian filaria is *Filaria bancrofti*, it may be that the absence of periodicity is a partial adaptation to the habits of its usual intermediary host in Fiji—*Stegomyia pseudoscutellaris*—a mosquito which feeds by day only. This absence of periodicity in the Fijian filaria does not depend on the habits or any racial peculiarity in the human host, for, if a native of India or the Solomon Islands comes to reside in Fiji, his microfilariae retain their habit of nocturnal periodicity; but when a stranger acquires filarial infection in Fiji, the corresponding microfilariae exhibit no such periodicity, but in this respect comport themselves in the same way as the microfilariae of the native Fijian.

IV. The principal expression of filarial infection in Fiji is the same as elsewhere, viz., elephantiasis.

V. The lower extremities and scrotum are the parts of the body most frequently affected, but in comparison with the natives of China, India and the West Indies, the natives of Fiji, and probably of other

Pacific Islands, are peculiarly liable to elephantiasis of the upper extremities; on the other hand, chyluria, lymph scrotum, varicose groin glands, and other forms of lymphatic varix depending on filarial obstruction of the thoracic duct above the entrance of the chyle vessels are rare. In many cases adult filariæ occur in large numbers in the tissues, especially in the lymphatic glands and vessels, but also in other tissues, the epididymis, testis and tunica vaginalis. In the latter circumstance may lie a contributory cause to the well-known infecundity of the Fijian.

VI. In the situations mentioned, the adult filariæ may die and become cretified.

VII. The adult filaria is not infrequently the cause of abscess, of hydrocele, enlarged testis and of thickening of lymphatic vessels, and even of fugitive swellings resembling Calabar swellings; but whether alive or cretified they are the direct cause of fibrosis and blocking of lymphatic glands and channels. Calcified filariæ have been found in the interior of and blocking the vasa efferentia of the epididymis.

VIII. The microfilariae produced by the parent worm may not reach the general circulation, perishing in the gland or organ in which the worm is lying.

IX. The occurrence of periodical attacks of lymphangitis, orchitis and funiculitis, can best be explained by periodical discharges of microfilariae from the parental uterus.

X. After such inflammatory attacks, the parent worm may perish.

XI. Lymph from such inflammatory foci may be sterile or may be the seat of bacterial invasion, but lymph abstracted from elephantoid tissue is usually sterile.

XII. Though the precise mechanism of the production of elephantiasis has yet to be determined, that the filaria is a principal factor is hardly open to doubt.

XIII. Surgical and medical treatment of filarial disease being unsatisfactory, mosquito destruction directed especially against the important intermediary host, *Stegomyia pseudoscutellaris*, is the only means likely to prove of service in mitigating this important form of helminthiasis in these islands.

I will now proceed to detail some of the facts on which these conclusions are based.

*I. 1,320 natives of all ages, for the most part of Fijian blood (there were a few Tongans and Samoans resident in the group) were examined for microfilariæ. Of these, 804 were males and 516 females; a larger proportion of the males, 30·4 per cent., were found to be infected. This apparent predisposition of the male sex to infection appears to be the rule in most countries—an exception apparently occurring in British Guiana, where DANIELS and CONYERS found twice as many females as males infected. The age incidence was found to be greatest after the twentieth year. The youngest child in whose blood microfilariæ were found was a girl of about five years of age. The microfilaria rate was found to vary in different parts of the group. By means of the co-operation of the native chiefs, a complete filarial census was made of certain districts. In Bau, the ancient native capital, the rate was found to be 12·5 per cent., whereas in another island, some two hundred miles away, it was found to be three times as large.

Adult filariæ were obtained from six cases, four times in lymphatic glands at operation, such as the groin and epitrochlear glands, once in an abscess situated over the epitrochlear gland, and once in enlarged groin glands postmortem. In only two of these cases were microfilariæ found in the blood stream, and these observed no periodicity. I wish to express my gratitude to Dr. J. F. SMALLEY, of the Colonial Medical Service, to whose cordial co-operation and operative skill the recovery of these particularly evasive parasites is due. About twenty-four adult worms, both males and females, were obtained alive, though only a small proportion were unlacerated. No less than thirteen were found in an epitrochlear gland, the size of a pigeon's egg—of these, five were removed intact.

In the physical examination of Fijians, a large proportion, 36·6 per cent. of the males and 18·4 per cent. of the females, were found to be suffering from what is regarded as to some extent presumptive evidences of existing or antecedent filarial infection (such as enlarged testis, enlarged groin glands, hydroceles, etc.), but in whose blood no microfilariæ could be found. On the other hand a large proportion of the population are apparently tolerant of the parasite; though their blood may be teeming with the embryos they may exhibit no ascertainable

* The number at the commencement of each paragraph refers to the conclusions already stated, and thus avoids unnecessary repetition.

signs of disease. Thus out of the total number harbouring microfilariæ in the blood, no less than 75 per cent. of the females and 31 per cent. of the males showed no gross signs of filarial disease.

A high degree of eosinophilia was present in nearly all the Fijians examined, whether microfilariæ were found in the blood or not—a fact previously pointed out by WILSON.

By means of a total white, red and differential blood count I was able to ascertain that an eosinophilia of from 8 to 11 per cent. is commonly present in (a) normal Fijians, without microfilariæ, and in whose stools no ova of intestinal parasites could be found; (b) in normal Fijians without microfilariæ, but in whose stools ova of intestinal parasites (*Ankylostoma duodenale* and *Tricocephalus dispar*) were present; (c) in Fijians with microfilariæ and evidence of intestinal parasites; (d) in Fijians with microfilariæ but without intestinal parasites; (e) in Fijians with elephantiasis but without microfilariæ; (f) in Fijians with elephantiasis and microfilariæ in the blood; (g) and in Fijians with signs of filarial disease other than elephantiasis.

In Europeans bred and born in the colony but with no signs of filariasis, an eosinophilia of 3 per cent. was found; but in six harbouring microfilariæ it was 8 per cent.; and in those suffering from various symptoms of filarial disease, but with no microfilariæ in their circulation, it averaged 9·8 per cent.

In seven instances the microfilariæ were observed to disappear suddenly from the blood-stream in which but a few hours before they had been numerous. In these cases the microfilariæ were never found again on subsequent examinations, although large quantities of blood (2 cc.) were aspirated from a vein and centrifuged in citrate solution. In every case some inflammatory disturbance, such as lymphangitis, adenitis or orchitis, preceded the disappearance of the parasites. In one instance, though present during the height of the fever, they vanished directly the temperature became normal.

To ascertain if possible the circumstances which cause the total and rapid disappearance of the microfilariæ, special experiments were undertaken with microfilariæ kept in sterile wellied slides under different conditions of environment and temperature. Microfilariæ, obtained by centrifuging quantities of blood, were kept for a number of days in normal serum, in serum from cases of elephantiasis, and also from cases

of orchitis during the height of the febrile attack and after the microfilariae had vanished from the patient's circulation. It was found that in normal serum and blood they lived much longer when kept at temperatures lower than that of the body, but died in a short time when kept at a constant temperature of 104° and 105° F.; that, notwithstanding this observation it does not altogether explain disappearance of the microfilariae from the circulating blood in so short a time as is the case where the parent worm dies, for it must be borne in mind that *Microfilaria immitis* when injected into the veins of a normal puppy, in which infection with adult filariae was excluded, can be found in the circulation and alive after a period of ten months, as has been shown by FÜLLEBORN.

II.—(1 a). THORPE first pointed out that the microfilariae found in the Tonga Islands observed no periodicity, though held to be morphologically identical with *Microfilaria bancrofti*; it was suggested at the time that this lack of periodicity might be due to the irregular habits of the islanders.

Since then, American workers, notably ASHBURN and CRAIG, have found in the Philippines a microfilaria also observing no periodicity. This they regarded as a new species and named it *Filaria philippinensis*, and as such it is described in several modern text books.

The Fijian microfilaria also observes no periodicity, as was pointed out by LYNCH in 1905. The charts I made with measured quantities of blood taken every four hours in ten instances, fully bear this out. Out of 114 filariated Fijians, in 91 microfilariae were present in large numbers, both by day and by night; the remaining 23 were useless for determining periodicity, as the small infection was too small, only one, or at the most two, microfilariae being found per slide.

(2 b) Seven species of mosquito were collected in Fiji, and with the four species most commonly encountered, namely, *Stegomyia pseudo-scutellaris* (Theob.), *Stegomyia fasciata* (Fab), *Culex fatigans* (Wied), *Culex jepsoni* (Theob.), transmission experiments were undertaken. The experimental insects were all bred from larvæ in confinement. The same patient (a Fijian) whose blood teemed with embryos, the number of which were estimated by frequent examination, was used for the feeding experiments which extended altogether over a period of nine months. The development was studied in dissections in normal saline solution and in celloidin sections.



P. H. Bahr del., 1911.

Fig. 1.

Filariae in thorax and travelling forward into proboscis on the tenth day of development in *Stegomyia pseudoscutellaris*, November, 1910. Camera Lucida drawing.

Reproduced by kind permission of Messrs. Witherby & Co.



P. H. Bahr *del.*, 1911.

Fig. 2.

a.—Section of a thickened brachial lymphatic containing portions of dead filariæ undergoing disintegration and blocking the lumen of the vessel. Note the large amount of fibrosis.

b.—Giant-cell formation within the calcified shell of the dead filaria.



P. H. Bahr *del.*, 1911

Camera Lucida drawing.

Reproduced by kind permission of Messrs. Witherby & Co.

In *Culex fatigans*, the development of the filaria took place normally but sparingly; in the majority of specimens the parasite died out altogether. Though great numbers entered the thoracic muscles, after the seventh day never more than two developing filariæ were found in the thorax of any individual mosquito, and never more than one in the proboscis. The cycle took nineteen days to complete.

In *Stegomyia pseudoscutellaris*, however, development took place to an extraordinary degree. This is a comparatively recently recognised species of mosquito, differing in a few minor points from its cogener, *Stegomyia scutellaris*. It was first described by THEOBALD, from specimens sent home from Fiji by JEPSON, the Government entomologist.

In the cooler months, the development of the filaria in *Stegomyia pseudoscutellaris* took twenty-one days to complete, but in the hot months it was much more rapidly effected, filariæ being commonly found in the proboscis on the thirteenth, and even as early as the tenth day after feeding. The number of filariæ in the thorax of a mosquito was in many instances extraordinary. On the sixteenth day of development, no less than 38 large forms, mostly over 1 mm. in length, were found in the thorax of one of my mosquitoes. Two separate broods of filariæ were successively transmitted through the same batch of mosquitoes. In one such mosquito, no fewer than fifty-four filariæ were found; thirty-three of them were over 1 mm. in length, the remaining twenty-one were small, being only in the third day of development. As many as five fully developed forms were found in the proboscis of one insect.

Stegomyia pseudoscutellaris is undoubtedly the commonest and most aggressive species of mosquito found in Fiji. It is especially common in the mangrove swamps along the coast line. It feeds only during the day time. I may add that the mortality in captivity amongst my filaria infected specimens was very heavy. To keep them alive successfully, a daily feed of blood is apparently required.

In *Stegomyia fasciata* the filariæ entered the thorax, but except in two instances no development took place after the seventh day of ingestion. However, in these two specimens the filariæ were 3 mm. in length, and possessed an alimentary canal. It is possible, therefore, that occasionally full development may take place in this species.

In *Culex jepsoni*, although over 60 infected specimens were dissected, no development of the filaria took place beyond a very early stage.

Lifeless "sausage-shaped" forms could be recognised in the dissections of the thorax up to nineteen days after feeding.

As regards the actual mode of development of the Fijian filaria in the mosquito, I have little to add to what has already been so ably written on the subject by Low and others, and it is in every detail, so far as I could ascertain, the same as that described for *Filaria bancrofti*. Considerable variation in development during different months and even in the same mosquito was noted. The forms in the proboscis measured .9-1.6 mm. in length.

When the worm is about half-grown a considerable space between the body cells and the cuticle is often apparent; probably at this time, as described by JAMES, an ecdysis takes place. The number of terminal papillæ which appear after this stage seems to be variable. ANNETT, DUTTON and ELLIOTT state there are four, whereas ASHBURN and CRAIG in *Filaria philippinensis* only found three. Apparently, as far as I could ascertain, three terminal papillæ is the usual number, though occasionally a fourth postanal papilla could also be made out.

In celloidin sections passing through the centre of the thorax of *Stegomyia pseudoscutellaris* certain peculiar elongated bodies, apparently formed of chitin, were found. In the interior of these bodies the coiled up remains of dead filariæ in various stages of development could be distinguished. In the thorax of *Culex fatigans* dead filariæ in a granular degenerating condition, often of large size were found, but no forms encapsuled as in *Stegomyia pseudoscutellaris*. I frequently saw two or three filariæ emerge together from the proboscis of the mosquito through DUTTON's membrane. FÜLLEBORN, by ingeniously arranged experiments, has shown that the larval *Filaria immitis* enters its canine host by boring through the skin. Opportunities occurred in Fiji for observing the human filaria similarly engaged. Filariæ dissected out from the thorax and proboscis of infected mosquitoes were placed, by means of a fine needle, on the human skin, and their behaviour watched through a strong hand lens. After a few convulsive movements they rapidly disappeared into the follicles of the skin. This experiment was repeated eight times, and always with the same result.

II. —(2a). The Fijian microfilaria was examined both alive and stained in various ways. No morphological differences between it and *Microfilaria bancrofti*, obtained from the blood of recently arrived East

Indians or Solomon Islanders, could be distinguished. A number of measurements of live specimens were made of the two forms, that with and that without periodicity, and were in close agreement.

By prolonged staining with dilute giemsa, a definite elongated structure, ending in a globular swelling, and of a bright red colour, could be distinguished occupying the space termed the "central viscus," in both the Fijian microfilariæ and in *Microfilaria bancrofti*. This probably represents the "granular mass" of MANSON and the "Innenkörper" of FÜLLEBORN, though it is curious to note that only a few microfilariæ in any given slide took the stain in this manner. FÜLLEBORN has shown that a similar body is present in *Microfilaria perstans* and in *Microfilaria loa*.

II.—(2b). Measurements of the parental form of the Fijian filaria were made directly after removal from the tissues and were in agreement with those given for *Filaria bancrofti*: the largest female measured 67 mm. in length and the largest male 29 mm. I understand from Dr. LEIPER, to whom the specimens were submitted and who was so kind as to examine them for me, that he is unable to distinguish any morphological differences between them and others coming from British Guiana and from India.

II.—(2c). In the course of numerous surgical operations and at three postmortems in Fijians, live filariæ as well as their calcified remains were found a great number of times, usually in association with lymphatic tissues, but also in other organs, as follows:—*Lymphatic glands*: inguinal, iliac, lumbar, mesenteric, bronchial, superficial cervical, and epitrochlear. *Organs*: testis, epididymis, spermatic cord and tunica vaginalis.

In a physical examination of a number of natives, glandular enlargement was found in 25 per cent. and was the commonest filarial lesion. Enlargement of the epitrochlear glands was found in no less than 22 per cent. Hydrocele and enlarged testes in the male sex came next in order of frequency, and it was just in these organs, glands and testes, that adult filariæ were most frequently met with.

II.—(2d). I was able to study the development of the non-Fijian *Microfilaria bancrofti* in *Stegomyia pseudoscutellaris* on three separate occasions, and to determine the efficiency of this insect as regards this variety of the filaria. The mosquitoes were induced to feed at night by placing the cages in a strong light after a period of starvation. All

stages of development were exactly similar to those observed in the Fijian variety and the ingested filariæ developed, both as regards numbers and rapidity, in the same remarkable way.

III. In the large number of Indians and Solomon Islanders examined by me in Fiji, only in those who had been resident in these islands under a period of three years were microfilariæ having a nocturnal periodicity met with.

In 120 East Indian coolies, *Microfilaria bancrofti* (*Filaria nocturna*) was found in five—all resident in Fiji under three years. Seven of these 120, however, harboured microfilariæ observing no periodicity; these Indians had been resident in Fiji for periods ranging from four to thirty years. I was given to understand that filarial disease is rare in the Solomon Islands. I found, however, six cases of filarial infection in seven Solomon Islanders who had been resident in Fiji from ten to thirty years. Their microfilariæ observed no periodicity.

A considerable number of Europeans scattered about these islands in isolated spots were found to have filariasis. Thus, out of nine Europeans examined in one locality, four had microfilariæ. In every instance in which microfilariæ were found in a European they were of the non-periodic type.

In attempting to explain the object and mechanism, so to speak, of filarial periodicity, we have to bear in mind that the phenomenon is exhibited by two species of microfilaria which, though practically identical as regards shape, size, anatomical features and movements, exhibit exactly opposite periodicity, and that a third with exactly the same characteristics exhibits no periodicity whatever.

Too much must not be made of the presence of large numbers of filariæ in the lungs in discussing this question of periodicity. *Microfilaria perstans* and *immitis* are found most plentifully in the internal organs and especially in the lungs; similarly in a postmortem of a Solomon Islander long resident in Fiji and whose microfilariæ observed no periodicity, I found the largest number in sections and smears of the lung. The lack of periodicity of the Fijian microfilaria may be a partial adaptation to the habits of its intermediary host, *Stegomyia pseudoscutellaris*, in much the same way as the nocturnal habits of *Microfilaria bancrofti* are an adaptation to the well-known habits of its favourite intermediate host, *Culex fatigans*.

IV. Elephantiasis is a common disease throughout the group. The rate varies greatly in different islands, and is much higher in the eastern than in the western part of the group. There are localities where it is extremely prevalent.

The rate for the total Fijian population examined was 3·5 per cent. The male sex is more frequently affected than the female, in the proportion of three to one.

The statistics collected clearly indicate that wherever the microfilaria rate is a large one, there also the greatest number of cases of elephantiasis are to be found. Thus, in the island of Lakemba, 44·1 per cent. of the males over twenty years of age had microfilaria in their blood; no less than 85·6 per cent. had physical signs of filarial disease, and 22 per cent. where the subjects of elephantiasis.

Elephantiasis is a coast disease in Fiji; rarely, as far as I could ascertain, are cases encountered in villages in the interior. In this respect, mainly, its range is coterminous, also as far as I could ascertain, with that of *Stegomyia pseudoscutellaris*, which abounds in the mangrove swamps surrounding the coast villages.

V. Out of forty-seven cases of elephantiasis the legs and scrotum were affected in twenty-four; the arms alone in ten; the arms and legs in six; both arms, legs and scrotum in five; arms and scrotum in one, and breast in one.

It would be interesting to know whether the frequency with which the upper extremities are affected bears any relation to the habits of the natives, seeing that, according to different authorities, these upper extremities are comparatively rarely affected in India, China and the East. Curiously enough, chyluria is a rare disease in Fiji—I did not see a single case. Dr. B. GLANVILL CORNEY, for twenty years Chief Medical Officer in Fiji, has informed me that he only remembers having seen one case. Again, the condition known as lymph scrotum does not appear to have been recognised in these islands at all. Lymphatic varices in the groin, reducible on pressure, and known as varicose groin glands, are also very rare—I only saw one case in which the mass could be reduced. The condition known by this name in Fiji, really consists of large masses of enlarged and fibrosed lymphatic glands, often two to three inches in diameter. It is very common.

VI. WISE, in British Guiana, first showed that, after its death.

calcification of *Filaria bancrofti* takes place in much the same way as in *Filaria medinensis*. I found such calcified forms to be extremely common, and was able to demonstrate them in almost every example of pathologically enlarged lymphatic tissues removed in Fiji. In one postmortem, fifteen calcified filariæ were found in the epididymis and scattered throughout the lymphatic glands. In the walls of hydroceles removed at operation they were found a number of times and in great abundance.

By decalcifying in VON EBNER'S solution, microscopical sections of these filariæ were obtained. In many, minute points, such as the structure of the ova and embryos, can still be recognised, the whole worm being surrounded by dense strands of fibrous tissue. In sections of the epididymis the calcified filariæ were found coiled up in the vasa efferentia, from which the ciliated epithelium had in part disappeared.

It is possible that the predilection of the filariæ for the generative organs in the male sex, and the destruction of glandular tissue caused by their presence, may, in part, account for the well-recognised infecundity of the native Fijian.

VII. Abscesses, generally situated in the groin or axilla, are of extremely frequent occurrence in countries where the filaria is common; adult filariæ have been found in such abscesses by MANSON and PRESTON MAXWELL in China, and by others. In an abscess situated over the epitrochlear glands, and which commenced as a filarial lymphangitis, I found two recently dead adult filariæ. They were surrounded by pus from which *Staphylococcus pyogenes aureus* and *Streptococcus pyogenes* were cultivated. Such abscesses are extremely frequent in Fijians.

Thickening of the lymphatic vessels of the upper arm and thigh could be made out in 9·7 per cent. of all individuals examined. One such cord was dissected out at operation, and a partially calcified adult filaria was found in it. Microscopical examinations of this lymphatic showed the remains of several adult filariæ completely blocking the vessel and surrounded by organising lymph and fibrous tissue.

Evanescient swellings, like Calabar swellings, appearing on the upper arm, abdomen and back, were frequently seen in subjects of filariasis. They were accompanied often by febrile disturbance.

Thrombosis of the median, internal saphenous and axillary veins was also noted. Synovitis of the knee-joint in conjunction with other filarial

symptoms was met with twice. The purulent fluid obtained from the knee-joint was sterile on culture.

Microscopical sections of lymphatic glands, from which adult living filariæ were removed, exhibit an invasion of fibrous tissue displacing the glandular elements. In the large hard glands removed from the groin, the glandular portion is confined solely to the cortex, whereas the central portion is occupied by fibrous tissue. The changes are the same in all such enlarged glands, *i.e.*, the groin, the epitrochlear, lumbar, mesenteric and cervical, all of which were examined microscopically.

On several occasions sections of dead filariæ encircled by bands of fibrous tissue were found in the gland substance. In such instances, large giant cells in close apposition to the dead filaria were frequently present. Such giant cells were seen also in microscopical sections of other lymphatic glands, although no calcified filariæ could be found in the same gland. The giant cells were surrounded by a peculiarly hyaline homogeneous substance which, it is suggested, represented stagnated and organising lymph.

Sections of the epididymis from which calcified filariæ were obtained demonstrate fibrosis of such a degree that little of the original structure of the organ can be distinguished.

Numbers of eosinophile cells were found in a peculiar kind of sticky exudate, which was found surrounding the adult filariæ. In sections of filariated glands eosinophile cells were exceedingly common, and in some instances constituted the main cell elements.

VIII. Microfilariæ were recovered on several occasions by means of gland puncture when none could be found in the patients' blood, even when large quantities, abstracted at the same time, were centrifuged. It was noticed that many of these microfilariæ were lifeless and in a disintegrating state. Similarly, microfilariæ have been obtained from the lymphatic glands by means of puncture during an acute attack of lymphangitis.

The laying down of fibrous tissue in response to chronic irritation from the presence of the adult parasite undoubtedly interposes a barrier to the passage of her microfilariæ, and thus prevents their entrance into the general circulation. In this may lie the explanation of the remarkable invasion of the lymphatic glands by adult filariæ without the presence of corresponding microfilariæ in the blood-stream.

IX. The production of lymphangitis, adenitis and orchitis, so frequent an occurrence in filarial invasion, requires explanation.

I was extremely fortunate in possessing a Fijian cook, the subject of recurring attacks of adenitis and orchitis, accompanied by rigors and high fever. I had him under minute and constant observation over a period of ten months. In his case the number of microfilariae in the blood-stream suffered no diminution after the febrile attacks. During each attack of orchitis a collection of fluid was noticed in the tunica vaginalis. On aspiration this fluid was found to consist of a thin purulent material containing numbers of microfilariae, many of which were active, whilst others were dead and undergoing disintegration. After the cessation of the inflammation this exudate became absorbed. The fluid remained sterile on culture. It is probable that the sudden and periodic discharge of microfilariae into the tunica vaginalis originated these periodic attacks of orchitis in much the same manner as the production of Calabar swellings in the analogous infection with *Filaria loa*, as has been suggested by MANSON.

The presence of microfilariae in the blood-stream is not essential to the production of lymphangitis. Cases were encountered in whom, while suffering from a typical lymphangitis, no microfilariae could be found in the blood.

X. In the present state of our knowledge, it is not possible to ascertain the number of microfilariae produced by one adult worm, and consequently we are unable to estimate the effect of the death of one or more adult parasites on the numbers of circulating microfilariae. Should the production of lymphangitis be due to the sudden emission of embryos into the lymphatic system, then it would be reasonable to suppose that the death of the parent worm itself is also the direct result of such an inflammatory disturbance. The frequency with which dead and calcified filariae were found in lymphatic glands and in the testis—organs so frequently the seat of such inflammatory disturbances—lends support to this supposition. In one instance, a dead and partially calcified female filaria was found in a brachial lymphatic six weeks after an attack of lymphangitis in that region.

There apparently exists in Fiji another febrile condition due to filarial infection. Such cases were seen amongst the Fijians in their native villages. This is the condition rightly designated as filarial fever.

Microfilariae, for the most part, were absent from the blood-stream. There were frequent rigors, the eyes were bloodshot, and there was a marked leucocytosis. After forty-eight hours all symptoms had disappeared. It is possible that the condition may be due to an internal lymphangitis. I obtained a postmortem on one case directly after such an attack. A great number of calcified filariae were present in the glands. In the epididymis a recently dead and disintegrating filaria, surrounded by a purulent exudate was found. All the lymphatic glands were enlarged and contained large areas of stagnated lymph and giant cell formation. Many microfilariae in a disintegrating condition were found in exudate from the lymphatics of the epididymis, but none in the blood.

XI. Lymph obtained by gland puncture in cases of lymphangitis always proved sterile, whether inoculated on to agar, blood agar or hydrocele fluid. The supervention of an infection by septic micro-organisms was noted in two cases, one of which died from septic absorption consequent on the formation of a psoas abscess, which, tracking into the hip-joint, destroyed the acetabular cavity. The case commenced as an orchitis and adenitis. Microfilariae were numerous in the blood, but disappeared suddenly, and streptococci could be cultivated from the gland exudate. In the second case the glands which had been inflamed for a long period were excised. A dead filaria was found coiled up in the centre of the gland, and a staphylococcus was cultivated from the purulent exudate. Microscopical sections showed giant cell formation. Cases of a similar nature have been recorded by WISE in British Guiana. It is probable that general septic infection supervening on filarial lesions is of general occurrence, and that the replacement of the glandular elements by fibrous tissue will necessarily create a *locus minoris resistentiae*.

The lymph obtained by puncture from elephantoid tissue in cases of elephantiasis proved sterile on culture. I had only one opportunity of examining the lymph during a febrile attack in a case of elephantiasis, and this, too, proved sterile. All observers are agreed that repeated attacks of lymphangitis precede the production of elephantiasis. Cases have been recorded by Low in which elephantiasis had supervened without any febrile disturbance. A similar case was met with in a white trader in Fiji who gave an intelligent and accurate history of his disease.

The sterility of the lymph in cases of lymphangitis, observed by me in Fiji, is in contradiction to the experiences of LE DANTEC and DUBRUEL, who have found staphylococci and streptococci in this fluid. The microbic origin of tropical lymphangitis receives support also from the researches of SABOURAUD on elephantiasis nostras, which apparently is due to a primary streptococcal infection of the lymphatics.

XII. It is not necessary, in my opinion, to assume a microbic infection for the production of elephantiasis. I have satisfied myself that the blockage of the lymphatic glands and lymphatics takes place by the filaria itself, and by the laying down of fibrous tissue in response to the presence of the parasite. I consider that lymph stasis may be produced in the following ways:—

Blockage of lymphatic vessels.

(1) Mechanical obstruction by the body of the living filaria and by its calcified remains.

(2) Changes in the vessel wall, by fibrosis, and by proliferation of the endothelium, eventually leading to organization of the thrombosed contents.

Blockage of the lymphatic glands.

Extensive fibrosis of the gland substance or by blockage of the efferent and afferent lymphatic trunks.

It is my belief that the production of tropical elephantiasis can best be explained by the blockage of lymphatic glands and channels by frequent and long continued invasion by filarial parasites.

XIII. Intravenous injections of antimony tartrate (gr. 1), atoxyl (gr. 1), and quinine (grs. 5 to 10), produced no diminution, transient or permanent, in the numbers of circulating microfilariae.

A number of observations were made on the breeding habits of *Stegomyia pseudoscutellaris*, the chief carrier of filarial infection in Fiji.

It was found to breed by preference in brackish water. Under artificial conditions, the larvæ thrive in '75 per cent. saline solution. From experiments made to ascertain the food supply of the larvæ, it was found that algæ and living organisms are not essential for their existence, for they thrive equally well in sterile water to which sterilized vegetable material had been added. Weak solutions of copper sulphate (gr. 1 to a gallon of water) though not prejudicial to the more mature forms, was decidedly poisonous to newly hatched larvæ. By this means a large

collection of water, a swimming tank, which on my arrival in the colony provided me with all the mosquito larvæ I required, was for the last six months of my stay there kept entirely free from these insects.

The increasing prosperity of the Fiji group is attracting more white settlers every year. In certain districts a large proportion of the whites are infected with the filaria and are thereby exposed to a great deal of inconvenience, if not to danger to life. Although we already know some of the effects of this parasite, it is probable that future research will show that yet other pathological conditions are directly or indirectly due to its action. It is highly desirable that appropriate measures for mosquito destruction, on the same lines as those devised for malaria and yellow fever, should be instituted, such measures having special reference to the habits of *Stegomyia pseudoscutellaris*.

Much interesting and profitable research on the subject of filariasis in the Pacific remains to be done. The following suggestions as to lines of future investigation have occurred to me :—

(1) Should *Filaria bancrofti* and the filaria found in Fiji be the same species, can the periodicity of *Microfilaria bancrofti* be disturbed by long residence in these islands ?

(2) Does the microfilaria with a nocturnal periodicity normally occur in any of the islands of the Pacific and, if so what are the chief mosquito intermediaries ?

(3) The explanation of the apparent inefficiency of *Culex fatigans* to act as an intermediary host in Fiji.

(4) The exact nature and production of filarial lymphangitis.

(5) More detailed research on the pathology of elephantiasis.

(6) The life-span of the microfilaria ascertained by injection of human blood containing these embryos into a monkey or a man.

(7) The earlier stages of *Filaria bancrofti* after its entrance into its human host.

(8) The determination of the respective geographical ranges of *Stegomyia pseudoscutellaris* and the non-periodic filaria.

(9) The determination of the microfilaria, the adenitis, and the elephantiasis rates, for all the Pacific islands.

(10) The determination of the biological cause, or causes of filarial periodicity.

I cannot close this paper without expressing my indebtedness, during the whole course of the investigation, to Sir PATRICK MANSON, who has given me, as to many others before me, the benefit of his golden advice and ripe judgment. I wish, also, to thank Dr. DANIELS for his encouragement. To many medical officers in the Fijian medical service, with whom I was so pleasantly associated, I wish to express my gratitude, more especially to Dr. LYNCH, Chief Medical Officer, Fiji, and to Drs. PRIDEAUX, SMALLY and SMARTT.

At the conclusion of his paper Dr. BAHR gave a most interesting epidiascope demonstration of drawings, chiefly of microscopic preparations illustrative of his paper, and by the kindness of Messrs. Witherby & Co. two of these are here reproduced. Messrs. Witherby & Co. are the publishers of Dr. BAHR's complete monograph on the subject of Filariasis in Fiji, in which all the illustrations shown by Dr. BAHR will be included.

Dr. BAHR also showed specimens under the microscope, and other pathological specimens, besides a collection of mosquitoes.

The Chairman (Sir WILLIAM B. LEISHMAN) expressed to Dr. BAHR the warm thanks of the Society for his most interesting communication. He also congratulated him on the demonstration which he had given on the development of filaria and particularly on the points bearing on its relation to elephantiasis. The same feeling was also expressed by other speakers.

DISCUSSION.

Sir PATRICK MANSON: I agree with you, Sir, that the thanks of the Fellows of the Society are due to Dr. BAHR for the very valuable paper which he has read, and I also regard it as fortunate for us that he has chosen this Society as the medium by which these important observations have been published. Dr. BAHR's very original plan of giving his conclusions at the beginning is a good one, for we all know that very often when reading scientific papers one has to wade through a long series of pages of narrative and argument before one gets to the results.

There are a great many points in this paper about which, had I more time, I would like to speak. I will limit myself to one or two. The most important to my mind is the absence of periodicity in the Fijian microfilaria, although the infection is so clearly shown to be due to *Filaria bancrofti*. The identity with *Filaria bancrofti*, which Dr. BAHR claims for the Fijian parasite, is no doubt justified, seeing that so careful a helminthologist as Dr. LEIPER confirms his statement that the adult Fijian worm is in every respect similar to *Filaria bancrofti* from Asia and America. But the explanation of the strange fact that whereas the Asiatic and American microfilaria observes a well-marked nocturnal periodicity, the Fijian microfilaria observes no such periodicity, is by no means apparent. Since the Fijian *Filaria bancrofti* of to-day is specifically identical with the Asiatic *Filaria bancrofti* of to-day, it follows that both are derived from a common ancestor whose original home was either the Pacific or Asia. Whether the ancestral microfilaria was periodic or non-periodic in its habits it is impossible to say, but certain it is that in process of time it either lost or acquired a habit. Assuming the Asiatic variety to have been the original ancestor, then on its migration to the Pacific it acquired the habit of coming into the blood during the day as well as during the night; or, if we assume that the Pacific filaria was the ancestor then it, on migration into Asia, dropped the habit of coming into the blood during the day, reserving its activities for the night.

Dr. BAHR explains the day appearance of the Fijian microfilaria as having been determined by the day feeding habits of its intermediary host, *Stegomyia pseudoscutellaris*. In this he is probably correct. To me this change in a biological habit seems to indicate a new conception in pathological parasitology. In the case of small-pox and cow-pox we have a virus—presumably a protozoon—modified in virulence and habit by passage through the definitive vertebrate hosts. In the case of this microfilaria we have a biological habit modified by passage through an arthropode intermediary host. If the biological habits of a parasite can be so modified by passage through an arthropode intermediary, why not the pathological? Such an idea might carry the explanation of many difficulties in pathology; for example, the special virulence of malaria in certain localities, and possibly its capacity to produce blackwater fever. Perhaps the same applies to yellow fever and other tropical diseases.

It is much to be regretted that the wide experience which a research such as this brings to the investigator should not be permanently available. The special training—which no one knows better than myself—necessary for the study of filariasis, is to a certain extent wasted unless the work can be continued by the same investigator. Systematic investigation of filariasis in the islands of the Pacific, and indeed all over the tropics, is much to be desired.

Dr. C. W. DANIELS: I have little to add to what has been already said, but I will confirm Dr. BAHR's statement as to the rarity of chyluria in Fiji. In British Guiana that symptom was one of the common attendants of filariasis, but its prevalence varied greatly with race. People of mixed blood and Portuguese were much more affected than natives. It is perhaps not sufficiently realised that a very large number of species of mosquito are efficient carriers of filariæ; and, again, that one variety of *Mansonia* bites only in the first part of the night and another only in the early morning. It would be interesting to know if biological peculiarities such as these have any influence on periodicity of the filaria in the infected persons.

Dr. G. C. LOW: I regard Dr. BAHR's paper as an important addition to the pathology of elephantiasis, and he has certainly adduced a number of facts and ideas, which appear to be new and are of distinct importance. The presence, for example, of the adult filariæ so frequently in the lymphatic glands, and the pathological changes they produce there, are to my mind material factors in the etiology of filarial diseases, including under these, of course, elephantiasis. Up to the present time the filarial adults have usually been considered to inhabit the lymphatic trunks, and though this is very probably their ordinary seat of selection, Dr. BAHR's work now shows that they are by no means infrequent in the glands themselves, and that when there they may produce an enormous amount of fibrosis which must necessarily destroy the function of these structures altogether. Suppose, for example, the femoral chain of glands in SCARPA's triangle all being affected in such a way, then surely there would be a degree of lymph stasis in the corresponding limb, and if inflammation and other factors then were superadded, sufficient cause would exist for the production of true elephantiasis. It is my belief, however, that to

progress further in the pathology of elephantiasis we will require to know more about the lymphatic system generally, especially about the various anastomoses that may occur when a block in a main trunk takes place, and for this some comparatively easy method of injecting the lymphatics in the cadaver will have to be thought out.

The non-periodicity of the Fijian microfilaria is very interesting, and Dr. BAHR'S attempt to explain the reason of it is ingenious, though one can be by no means certain that it is the correct one. The fact that Dr. LEIPER has determined that the parent worms of this non-periodic embryo are identical in every respect with *Filaria bancrofti* from other parts of the world, is specially interesting to me, because, as Fellows of the Society will remember, I criticised at a former meeting of the Society somewhat severely Captain CRAIG'S attempt to create a new species of filaria in the Phillipines, on the grounds of non-periodicity and other points, and said that until adults had been examined he had no right to hold such a contention. Now that we find that another non-periodic filarial embryo from another group of Pacific Islands is just *Filaria bancrofti*, my suggestion of the Philippine one being *F. bancrofti* only and not a new species is correspondingly strengthened, and Captain CRAIG'S position is still further weakened. I believe that when our observations on filarial periodicity are widened, we will find that non-periodicity is not altogether so rare as is sometimes supposed. I have met with it in the West Indies, and I have slides taken from the blood of natives of the West Coast of Africa by day, which show embryonic *F. bancrofti*. The filarial expedition of the Liverpool School of Tropical Medicine noted this, and more recently CONNALL and others have found the same thing. Extended observations are required on this subject.

It is difficult to understand why *Culex fatigans* should be so inefficient a carrier in Fiji, while in the West Indies and other places it acts so well. That is, however, only another point amongst so many in filariasis that still requires solution, and the same may be said of the fact of chyluria being so rare or practically non-existent in Fiji. Many points of interest still await the worker in this interesting branch of helminthology.

Dr. R. T. LEIPER: I had an opportunity of comparing Dr. BAHR'S specimens of adult filariæ with those collected by Drs. MINETT and WISE

in British Guiana and others from India, and after a very careful examination even of the most minute points in the anatomy and morphology of these worms, I can distinctly say that there are no differences on which a specific distinction can be based.

Fleet-Surgeon BASSETT-SMITH: I would like to ask Dr. BAHR what is his explanation of the fact that so few men in the Navy develop filariasis, although they are continually in and out of ports where infection is very prevalent. Is it to be explained by any peculiarity in their clothing, their habits, constitutional differences, or the precautions which they take? He has also told us that the microfilariae die at a temperature of 104° F., and it would be interesting to know how far high fever influences the progress of the infection.

Dr. P. H. BAHR: In reply, I would state that it does not seem improbable that not only are the pathogenic, but also other, properties of protozoa and helminths modified by their passage through different intermediates which are able to transmit them.

In the case of bacilli it is probable that their cultural properties, as well as their virulence, will be found to be modified by their passage through the intestinal canal of a cold-blooded invertebrate.

There must be some chemical substance which determines the successful development of the filaria in a particular species of mosquito, or the reverse.

It would be interesting to find out whether the development of different protozoa, such as the malarial parasite, can proceed in a mosquito (*i.e.*, an anopheles) already infected with filaria. The presence of such a malarial parasite may be inimical to the filaria. This is merely a suggestion, but it is interesting to note that filariasis is said to be rare in the Solomon Islands and the New Hebrides, groups lying a thousand and six hundred miles north-west of Fiji respectively, where malaria is rife.

Much more work is required on the mosquitoes of the Pacific and their relationship to the diseases which occur there.

As regards the periodicity question. I don't think several members quite understood that a nocturnal periodicity was only found in

those Indian coolies who had been resident in Fiji for a period of less than three years; after that length of residence the non-periodic microfilaria was found.

This betokens one of two things: either that the habits of the original *Microfilaria nocturna* have become altered by local circumstances, or that the coolie has become reinfected with the Fijian filaria.

In reply to Dr. BASSETT-SMITH, let me say that in the Navy the men mostly sleep on board out in the harbour where there are no mosquitoes, or at least where the mosquitoes are not liable to become infected with filaria. The Europeans on shore, who live under better circumstances and apart from the natives, appear never to become infected. It is the class of white men who live with the natives and sleep in their houses which is principally affected.

Although *in vitro* high temperatures are fatal to microfilariæ, they are not always so clinically. Thus, a case of tuberculosis, with a hectic temperature, which I watched for a period of nine months, made no difference to a small number of microfilariæ in the blood-stream, and the same is true also of a febrile attack of dysentery.



